

NANOTECHNOLOGY IN ACTION





Nanotechnology is making an impact and improving our everyday lives by advancing technology and industry sectors, including:

- Consumer Electronics
- Textiles
- Sports
- Medicine
- Infrastructure & Construction
- Food & Agriculture
- Water Abundance & Safety
- Energy
- Quantum Information Science & Technology
- Artificial Intelligence

What is Nanotechnology?

Nanotechnology is the understanding and control of matter at the nanoscale, at dimensions between approximately 1 and 100 nanometers, where unique phenomena enable novel applications. A nanometer is one-billionth of a meter. For reference, a sheet of paper is about 100,000 nanometers thick. Matter can exhibit unusual physical, chemical, and biological properties at the nanoscale, differing in important ways from the properties of bulk materials, single atoms, and molecules. Some nanostructured materials are stronger or have different magnetic properties compared to other forms or sizes of the same material. Others are better at conducting heat or electricity. Nanomaterials may become more chemically reactive, reflect light better, or change color as their size or structure is altered.

Nanotechnology serves as the foundation for key industries of the future such as artificial intelligence, quantum information science, and advanced manufacturing. Nanotechnology innovations are ensuring continued U.S. leadership in the semiconductor and strategic computing industries, and are advancing many other national priorities, including space exploration, energy, advanced communications (5G/6G), healthcare, agriculture, aviation, and national security.

These are just a few examples of nanotechnology in action.

Teachers: Nanotechnology is interdisciplinary by nature and spans across many STEM subjects such as chemistry, physics, biology, engineering, mathematics, and materials science, offering exciting real-world applications for your students.

Learn more by visiting nano.gov.

Consumer electronics are empowered by nanotechnology. Products benefit from more powerful batteries, enhanced displays, and stronger, more durable materials.

Vibrant Screens

Quantum dots, tiny semiconductor crystals, are used in modern displays to produce purer colors and greater brightness. These systems generate precise wavelengths of light, giving screens, tablets, and phones more accurate color and improved energy efficiency.



New Realities

Extended reality devices use nanomaterials in displays and optical coatings to enhance visual clarity and responsiveness. Nanotechnology makes lenses lighter, reduces distortion, and increases interactivity for more immersive digital experiences. With emerging metamaterial lenses, optical systems can now be built without precisely curved glass or plastic, introducing a completely new way to design and manufacture lenses.



Durable Displays

Nanocoatings applied to screens and camera lenses reduce glare, resist smudges, and improve durability. These coatings keep devices clearer and cleaner, while extending the lifespan of displays used in everyday electronics.



Powering Wearable Tech

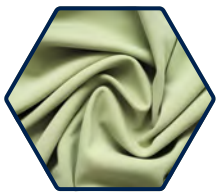
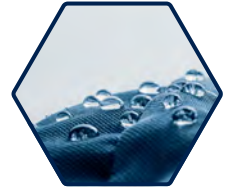
Lightweight batteries that power wearable technologies are made with nanosilicon-based anodes. This innovation dramatically increases the energy density of lithium-ion batteries, enabling smaller devices that charge faster and last longer between charges. These batteries power everything from electric vehicles to wearable electronics more efficiently.



Nanotechnology is transforming how fabrics perform by adding functionality, strength, comfort, and protection while keeping materials lightweight and breathable.

Water- and Stain- Resistant Fabrics

Nanocoatings create surfaces that repel water and resist stains without affecting softness or comfort. These advanced treatments keep clothing dry, cleaner, and longer-lasting.



Power-Generating Fabrics

Textiles embedded with nanotechnology can generate power from sources such as movement of the wearer, temperature gradients, or sunlight.

Odor Prevention

Smart textiles have fibers that can sense, react, and adapt to external stimuli while seamlessly blending into clothes. These wearable sensors provide non-invasive methods for monitoring health. For example, systems using smart fabrics can identify when newborns are in distress.



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Nanotechnology is redefining performance and safety in sports by making equipment lighter, stronger, and more durable.

Safer Helmets

Advanced helmets utilize liquid nanofoam filled with tiny pores and coated in water-repellent silicone that absorb and disperse impact energy. Unlike traditional foam, it bounces back after collisions, providing consistent protection for athletes.



Stronger, Lighter Cars

Motorsport vehicles use nanocomposites for lightweight body panels, nanoparticles in lubricants to reduce friction, and nanotechnology-enhanced paints to improve scratch- and heat-resistance. Advanced nanotechnology-enabled batteries increase charge range, recharge speed, and overall battery performance.

Stronger, High-Performance Equipment

Nanomaterials reinforce golf balls, baseball bats, tennis rackets, and hockey sticks, improving strength and flexibility. In golf balls, graphene particles provide better spin control, higher speeds, and longer driving distances. Nanomaterials used in bats, rackets, and hockey sticks enhance performance and durability without extra weight.



Bouncier Tennis Balls

Clay nanoparticle coatings in tennis ball cores help trap air and maintain pressure. This innovation allows the balls to bounce longer and perform more consistently during play.

Advances in medicine enabled by nanotechnology are revolutionizing the care we receive by providing tools to more quickly and accurately detect, diagnose, and treat disease.

Early Detection

Gold nanoparticles are used in rapid diagnostic tests—from viruses to pregnancy—to enhance sensitivity and accuracy. These nanoscale particles produce clear, visible results, enabling faster detection of illnesses at earlier stages.

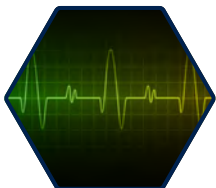


Accelerated Healing

Smart bandages convert body movements into gentle electrical pulses that stimulate tissue repair and regrowth. Additionally, sensors in smart bandages can detect infection without having to remove the dressing.

Transparent Sunscreen

Nanoscale titanium dioxide and zinc oxide absorb harmful UV rays while scattering visible light. The result is powerful sun protection that appears transparent on the skin instead of white or chalky.



Smarter Heart Monitors

Graphene “tattoo” implants, thinner than a strand of hair, that conform seamlessly to the heart’s surface may soon be on the market. In testing, they were able to sense and correct irregular heartbeats, offering a softer, more precise alternative to traditional pacemakers.

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Targeted Drug Delivery

Nanotechnology-enhanced formulations can significantly improve the solubility, stability, bioavailability, and targeted accumulation of drugs and vaccines. For example, a nanoscale liposomal formulation of a chemotherapeutic drug increases drug efficacy while reducing overall chemotherapy side effects.



Real-Time Health Monitoring

Wearable nanosensors with painless microneedles can continuously track medication levels in the body. This technology helps ensure that drugs like antibiotics remain effective without harming patients, supporting safer and more personalized treatment. This approach is also used to monitor glucose and insulin dynamics in people with diabetes.

Restoration

Nanotechnology has played a transformative role in restorative dentistry, one of the earliest fields to adopt nanoscale materials in clinical practice. By enhancing the strength, durability, and bioactivity of dental materials, nanotechnology enables longer-lasting restorations while actively supporting tooth repair and preventing decay.



Nanotechnology is strengthening and protecting our infrastructure by improving materials used to build roads, bridges, and buildings while reducing costs and environmental impact.

Smart Windows

Nanocoatings applied to glass allow windows to adjust tint in response to a small electric charge. This innovation improves energy efficiency by controlling light and heat levels in buildings.



Protecting Bridges

Nanomaterials are used in paints to create super-durable, self-cleaning, and anti-corrosion coatings. "Smart" coatings last longer, resist damage better, and reduce maintenance by enhancing barrier properties, improving adhesion, and providing advanced functions like self-healing or sensing.

Anti-Fouling Ship Coatings

Nanotechnology-based coatings prevent barnacles, algae, and other marine organisms from attaching to ship hulls. These slippery or growth-inhibiting surfaces improve fuel efficiency and reduce maintenance costs.



Corrosion- and Wear-Resistant Surfaces

Coatings made with nanostructured materials have improved adhesion strength as well as resistance to abrasion, fire, and chemicals. These properties are used to protect structures from corrosion and reduce associated repair costs.

Advanced Power Cables

Nanomaterial-enhanced cables are being developed to carry more electricity over longer distances with less energy loss. Lighter, stronger nanocomposite conductors can make the power grid more efficient and resilient.



Nanotechnology is helping to secure the global food supply by improving safety, sustainability, and freshness—from farm to table.

Smart Food Packaging

Nanosensors embedded in packaging can detect temperature changes, moisture, and pathogens in perishable goods. This technology alerts producers and consumers to spoilage, helping prevent foodborne illness and reduce waste.



Smarter Testing for Farmers

Low-cost nanoparticle-based systems measure herbicide levels in fruits and vegetables such as apples, corn, and strawberries. With faster, more accurate results, farmers can apply chemicals more precisely—reducing costs and environmental and public harm.

Targeted Delivery for Crops

Nanoscale vessels deliver pesticides, nutrients, or genetic materials directly to plants where and when they are needed most. This precision agriculture approach minimizes waste, increases yield, lowers environmental impact, and makes crop production more sustainable and cost-effective.



Safer, Fresher Foods

Nanotechnology is transforming food packaging into an active system for preserving quality and safety. Advanced packaging can detect contaminants, while nanocomposites in containers keep drinks carbonated and food fresh longer. These innovations protect consumers and reduce spoilage across the supply chain.

Smarter Environmental Detection

Nanoengineered sensors can detect chemical and biological agents in air and soil with exceptional accuracy. Plug-in nanosensors for smartphones will soon allow instant, on-the-spot detection of pathogens, pollutants, and crop diseases.



Nanotechnology is providing innovative solutions for a clean, safe, and sustainable water supply through advanced filtration, purification, and harvesting technologies.

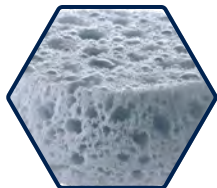
Affordable Water Purification

One example of point-of-use water purification is a ceramic water filter that combines pine resin with silver nanoparticles to remove bacteria and impurities. This simple, low-cost design disinfects water as it passes through, offering a sustainable option for communities with limited access to clean water.



Reusable Nanosponges

Sponges coated with nanoparticles can capture metals such as zinc and copper, as well as phosphates, from contaminated water. When rinsed in a low-pH solution, the pollutants are released, allowing the sponge to be cleaned and reused multiple times. This technology is also used to remove oil from water, for example, to address oil spills.



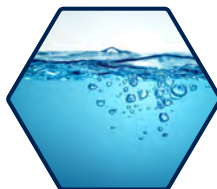
Harvesting Water from Air

Nanoporous materials such as zeolites and metal organic frameworks can collect moisture from dry air and release it as drinkable water when triggered by external stimuli. Due to their large surface area, a small amount of these absorbents can produce large amounts of potable water, providing a lifeline for water-stressed regions.



Water Purification

Nanotechnology is enabling more effective and accessible water purification. Nanomaterials such as graphene-based filters and nanoporous membranes can remove bacteria, viruses, heavy metals, PFAS, and other contaminants with high efficiency.



The energy sector is being revolutionized with nanotechnology by improving how we generate, store, and use power, making energy systems more efficient and resilient.

Rechargeable Long-Term Energy Storage

Advanced batteries with various chemistries and nanostructured anodes dramatically increase energy density and storage capacity compared to traditional lithium-ion batteries. These U.S.-developed batteries provide long-term storage options for energy resilience.



Enhanced Oil and Gas Operations

Nanotechnology enhances efficiency and safety across the oil and gas industry. Nanomaterials stabilize drilling fluids, nanocatalysts reduce refinery energy use, and nanomembranes filter contaminants from production water, making exploration and production more efficient.

Nuclear Energy

Nanomaterials are under development that are resistant to embrittlement and structural degradation from exposure to radiation, and will make nuclear energy reactors safer, longer-lasting, and more economically viable.



Thermal Management

Carbon-nanotube-based thermal interfaces help satellites dissipate waste heat from sensitive electronics. By preventing overheating, these nanoscale materials improve system performance, resilience, and longevity in extreme environments. This innovation is also being applied for energy management in data centers.

Quantum behavior occurs at the nanoscale, with applications in next-generation computing, sensing, and navigation.

Controlling Quantum Behavior

Researchers have discovered a new way to control electron spin in quantum dots using voltage pulses instead of magnetic fields. This breakthrough leverages the “spin-valley coupling effect,” improving control of quantum states and enabling more stable quantum systems.

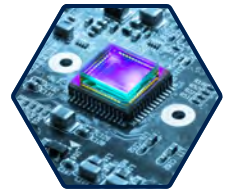


Mechanical Motion Meets Quantum Control

Nanomechanical oscillators coupled with nanoscale circuits can process energy as quantum bits, or qubits. This innovation allows scientists to manipulate quantum states with extreme precision, paving the way for next-generation computing and sensing technologies.

Ultra-Sensitive Quantum Sensors

Quantum sensors built with nanomaterials can detect minute changes in temperature, magnetic fields, and electric fields. These sensors make technologies like magnetoencephalography possible, mapping brain activity with unmatched sensitivity and detail.



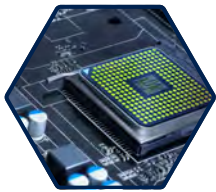
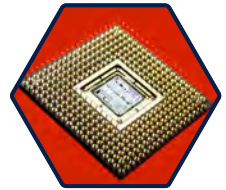
Artificial Intelligence (AI)



The future of AI is being fueled by nanotechnology with faster, smaller, and more energy-efficient chips that power intelligent technologies across every sector.

Smarter, Smaller, and Faster Chips

Nanoscale transistors make it possible to fit hundreds of billions of them on a single chip. This miniaturization enables faster and more powerful AI processors that use less energy and deliver higher performance in compact systems. Novel architectures combine compute and memory on the same chip, enabling AI applications through nanotechnology.



Faster Connections with Light

Today's nanotechnology-enabled processors send data through metal wires, which consume energy and generate heat. At the nanoscale, optical interconnects—tiny channels that use light instead of electricity—transfer data faster and more efficiently. This innovation helps AI data centers run cooler and process information more quickly and efficiently.

Thermodynamic Computing

Traditional processors generate energy as heat during operation. Thermodynamic computing, currently under development, uses nanoscale circuits that recover energy through reversible logic operations. This method dramatically increases energy efficiency and shows promise for powering AI systems with far less electricity.



Endless Possibilities

Nanotechnology is driving breakthrough innovations that improve lives, strengthen industries, and build a better future.

